

Exploring the Impact of Binaural Beat Auditory Stimulation and Noise-Reducing Headphones on Intraoperative Anxiety During Upper Limb Orthopedic Surgeries Under Regional Block

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ABSTRACT

Introduction: Intraoperative anxiety is common among awake patients undergoing surgery under regional anaesthesia. This study evaluated binaural beat auditory stimulation and active noise cancellation (ANC) for reducing anxiety during upper-limb orthopaedic surgery. **Materials and Methods:** This prospective randomized controlled trial included 90 patients undergoing surgery under supraclavicular block. Patients were randomized equally to binaural beats (Group A), ANC (Group B), or standard care (Group C). Anxiety was assessed using STAI-6, along with haemodynamic parameters, sedation, communication, and patient satisfaction. **Results:** Baseline STAI-6 scores were comparable among groups ($p=0.766$). At 30 minutes, anxiety was significantly lower in Group A (32.93 ± 2.64) than Group B (38.20 ± 2.52) and Group C (41.50 ± 8.62 ; $p<0.001$). Anxiety reduction was greatest with binaural beats (11.00 vs 6.40 vs 2.27 points; $p<0.001$). Group A also demonstrated greater sedation and higher satisfaction (9.23 ± 0.77 vs 8.33 ± 0.84 vs 6.43 ± 1.45 ; $p<0.001$). No major adverse events occurred. **Conclusion:** Binaural beats effectively reduced perioperative anxiety and improved sedation and patient satisfaction compared with ANC and standard care.

Keywords: Binaural beats; anxiety; noise cancellation; regional anaesthesia; STAI-6; orthopaedic surgery.

INTRODUCTION

Regional anaesthesia (RA) is an important component of contemporary anaesthetic practice, allowing surgery to be performed while maintaining consciousness and avoiding the need for general anaesthesia in appropriately selected patients [1]. However, patients undergoing surgery under regional anaesthesia remain exposed to the operating-room environment, and anxiety may persist despite adequate sensory blockade and absence of surgical pain [2]. Intraoperative anxiety may arise from unfamiliar surroundings, restricted movement, surgical drapes, conversations among operating-room personnel, and sounds generated by surgical instruments, potentially affecting patient comfort and satisfaction

[3]. This issue is particularly relevant during orthopaedic surgery, where substantial noise may be generated by drills, saws, hammers, metal instruments, and other equipment [4]. For an awake patient whose view of the operative field is obscured, exposure to unfamiliar surgical sounds may contribute to apprehension and heightened anxiety. Studies evaluating patients under regional or spinal anaesthesia have demonstrated that modification of the auditory environment through music, binaural beats, or noise reduction may improve perioperative anxiety and patient comfort [1,5,6]. Intraoperative anxiety may also be accompanied by physiological stress responses and changes in haemodynamic parameters. Preoperative and

perioperative anxiety have been associated with adverse perioperative experiences and may influence postoperative recovery [7]. Pharmacological anxiolysis and sedation, particularly with benzodiazepines such as midazolam, are frequently used to improve patient comfort. However, sedative medications may cause excessive sedation and other undesirable effects, and psychoactive medications have also been associated with postoperative delirium in susceptible patients [8,9]. These considerations have encouraged increasing interest in non-pharmacological interventions that may reduce anxiety while preserving consciousness and cardiorespiratory stability. Binaural beat auditory stimulation is a non-invasive auditory technique in which tones of slightly different frequencies are presented separately to each ear, resulting in perception of a rhythmic beat corresponding to the difference between the two frequencies [10]. Binaural auditory stimulation has been investigated for its potential effects on anxiety, cognition, and pain perception, with evidence suggesting possible anxiolytic benefits [11]. Clinical studies have reported reductions in perioperative anxiety with binaural beat interventions during cataract surgery, endoscopic procedures, and surgery performed under spinal anaesthesia [1,12,13].

Another approach is reduction of environmental noise through noise-cancelling headphones. By attenuating unwanted operating-room sounds, these devices may provide a less stressful auditory environment for awake patients. Previous studies have evaluated noise cancellation alone or in combination with music and reported potential reductions in anxiety or sedative requirements during procedures performed under regional anaesthesia [14,15]. Despite increasing interest in auditory interventions, evidence directly comparing binaural beat stimulation with noise reduction remains limited, particularly in patients undergoing upper-limb orthopaedic surgery under regional block. Therefore, the present study aimed to explore the impact of binaural beat auditory stimulation and noise-reducing headphones on intraoperative anxiety during upper-limb orthopaedic surgeries under regional block, along with their effects on haemodynamic parameters and sedation levels.

MATERIALS AND METHODS

This was a prospective, randomized, controlled clinical trial comparing binaural beat auditory stimulation, active noise cancellation (ANC), and standard intraoperative care. The study was conducted in the Department of Anaesthesiology, Rajendra Institute of Medical Sciences (RIMS), Ranchi, in the orthopaedic operation theatre over approximately 10 months after Institutional Ethics Committee approval.

Study Population

Adult patients of either sex undergoing elective upper-limb orthopaedic surgery under supraclavicular brachial plexus block were enrolled.

Inclusion Criteria

Patients aged 18–60 years, ASA physical status I–III, scheduled for elective upper-limb orthopaedic surgery under supraclavicular block, able to understand the study scales, and providing written informed consent were included.

Exclusion Criteria

Patients with refusal to participate/use headphones, hearing impairment, allergy to bupivacaine, infection at the block site, coagulopathy, psychiatric or cognitive disorders, substance abuse, or chronic sedative/opioid use were excluded.

Sample Size

Based on Ligree et al. [1], considering a mean STAI-6 difference of 6.0, pooled SD of 7.5, $\alpha=0.05$, and 80% power, 27 patients were required per group. After accounting for possible dropouts, 30 patients per group (total N=90) were included.

Randomization and Allocation

Computer-generated randomization was used, with allocation concealed using sealed opaque envelopes. Patients were allocated into three groups (n=30 each): Group A, binaural beat auditory stimulation; Group B, ANC without auditory stimulation; and Group C, standard care without headphones.

Pre-Anaesthetic Evaluation

All patients underwent routine pre-anaesthetic evaluation one day before surgery and were familiarized with the STAI-6, VAS, Ramsay Sedation Scale (RSS), and communication-difficulty scale.

Anaesthetic Technique

Standard ECG, non-invasive blood pressure, and SpO₂ monitoring were instituted. Ultrasound-guided supraclavicular brachial plexus block was performed using an 8–13 MHz linear probe and 22-G needle with an in-plane technique. Twenty millilitres of 0.25% bupivacaine was administered, and sensory and motor blockade was assessed after 15 minutes.

Study Intervention

Group A – Binaural Beats

Patients received binaural beat auditory stimulation through GoBoult Boost Hybrid ANC over-ear headphones with ANC switched off.

Group B – Active Noise Cancellation

Patients wore the same headphones with ANC activated but without music or binaural beats.

Group C – Control

Patients received routine intraoperative care without headphones and remained exposed to ambient operating-room noise. The interventions were initiated after surgical draping and continued until placement of the final skin suture.

Outcome Measures

Primary Outcome

Intraoperative anxiety was assessed using the six-item State-Trait Anxiety Inventory (STAI-6), with the primary endpoint being the difference in mean STAI-6 scores among the three groups.

Secondary Outcomes

Secondary outcomes included patient satisfaction, sedation level, communication difficulty, haemodynamic parameters, and occurrence of tachycardia or hypertension requiring intervention.

Data Collection

Data were recorded by an independent observer using a predesigned case record form. Haemodynamic parameters were recorded at predefined intraoperative intervals, while anxiety and sedation assessments were performed during the perioperative period.

Statistical Analysis

Data were analysed using SPSS version 26.0. Continuous variables were expressed as mean $\pm$ SD and compared using one-way ANOVA or Kruskal–Wallis test. Categorical variables were analysed using Chi-square or Fisher's exact test. A p-value <0.05 was considered statistically significant.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki after Institutional Ethics Committee approval (IEC registration no. ECR/769/INST/JH/2015/RR-21). Written informed consent was obtained from all participants, and confidentiality was maintained.

RESULTS

A total of 110 patients were assessed for eligibility; 20 were excluded and 90 were randomized equally into Group A (BNB), Group B (ANC), and Group C (control), with 30 patients in each group. All randomized patients completed the study.

Baseline demographic and clinical characteristics, including age, sex, weight, and ASA status, were comparable among the groups (all $p>0.05$) (Table 1). Baseline STAI-6 scores were also similar (43.93 ± 4.82 , 44.60 ± 4.00 , and 43.77 ± 5.12 ; $p=0.766$). Baseline SBP, DBP, and MBP were comparable, whereas heart rate differed significantly (83.33 ± 10.24 , 82.90 ± 12.10 , and 92.27 ± 18.41 bpm; $p=0.017$) (Table 2, Figure 1). At 30 minutes, STAI-6 scores were significantly lower in Group A (32.93 ± 2.64) than Group B (38.20 ± 2.52) and Group C (41.50 ± 8.62 ; $p<0.001$). Reduction from baseline was 11.00 ± 5.19 , 6.40 ± 4.21 , and 2.27 ± 9.47 , respectively ($p<0.001$). Postoperative STAI-6 scores showed a similar pattern (31.10 ± 2.15 , 36.45 ± 2.30 , and 43.20 ± 5.10 ; $p<0.001$) (Table 3). Intraoperative heart rate differed significantly among groups throughout surgery and at the end was 72.63 ± 7.78 , 73.90 ± 9.44 , and 92.97 ± 21.20 bpm in Groups A, B, and C, respectively ($p<0.001$) (Table 4, Figure 2). SBP differed significantly from 120 minutes onward, with end-of-surgery values of 127.47 ± 10.57 , 129.73 ± 12.48 , and 143.63 ± 20.33 mmHg ($p<0.001$). DBP at the end of surgery remained comparable ($p=0.204$), while MBP differed at 140 and 160 minutes ($p=0.039$ and $p=0.018$, respectively) (Table 5, Figure 3). RSS scores were significantly higher in Group A at 30 minutes (3.40 ± 0.62 vs 2.73 ± 0.64 vs 1.77 ± 0.57 ; $p<0.001$) and at the end of surgery (5.30 ± 0.53 vs 3.07 ± 0.58 vs 1.77 ± 0.57 ; $p<0.001$). Communication scores were 4.23 ± 0.63 , 4.37 ± 0.49 , and 4.90 ± 0.31 ($p<0.001$), while patient satisfaction was highest in Group A (9.23 ± 0.77), followed by Group B (8.33 ± 0.84) and Group C (6.43 ± 1.45 ; $p<0.001$) (Table 6). No block failure, local anaesthetic systemic toxicity, respiratory depression, profound bradycardia requiring intervention, or other sedation-related adverse events were observed.

Table 1. Baseline demographic and clinical characteristics of the study groups

Parameter	Group A: BNB (n=30)	Group B: ANC (n=30)	Group C: Control (n=30)	p-value	Statistical test
Age (years), mean $\pm$ SD	42.03 ± 14.19	36.60 ± 13.91	36.90 ± 16.47	0.289	One-way ANOVA
Male, n (%)	19 (63.3)	25 (83.3)	24 (80.0)	0.155	Chi-square test
Female, n (%)	11 (36.7)	5 (16.7)	6 (20.0)	0.155	Chi-square test
Weight (kg), mean $\pm$ SD	67.63 ± 12.12	65.57 ± 12.09	64.30 ± 13.75	0.591	One-way ANOVA
ASA I, n (%)	28 (93.3)	29 (96.7)	25 (83.3)	0.168	Fisher's exact

					test
ASA II, n (%)	2 (6.7)	1 (3.3)	5 (16.7)	—	Fisher's exact test

Table 2. Comparison of baseline haemodynamic and anxiety parameters

Parameter	Group A: BNB	Group B: ANC	Group C: Control	p-value	Statistical test
Heart rate (bpm)	83.33 ± 10.24	82.90 ± 12.10	92.27 ± 18.41	0.017	One-way ANOVA
SBP (mmHg)	151.27 ± 17.52	147.73 ± 16.32	147.67 ± 19.33	0.694	
DBP (mmHg)	81.40 ± 9.42	83.30 ± 11.23	77.80 ± 12.98	0.142	
MBP (mmHg)	100.50 ± 12.74	103.10 ± 11.44	97.40 ± 12.45	0.201	
STAI-6 score	43.93 ± 4.82	44.60 ± 4.00	43.77 ± 5.12	0.766	

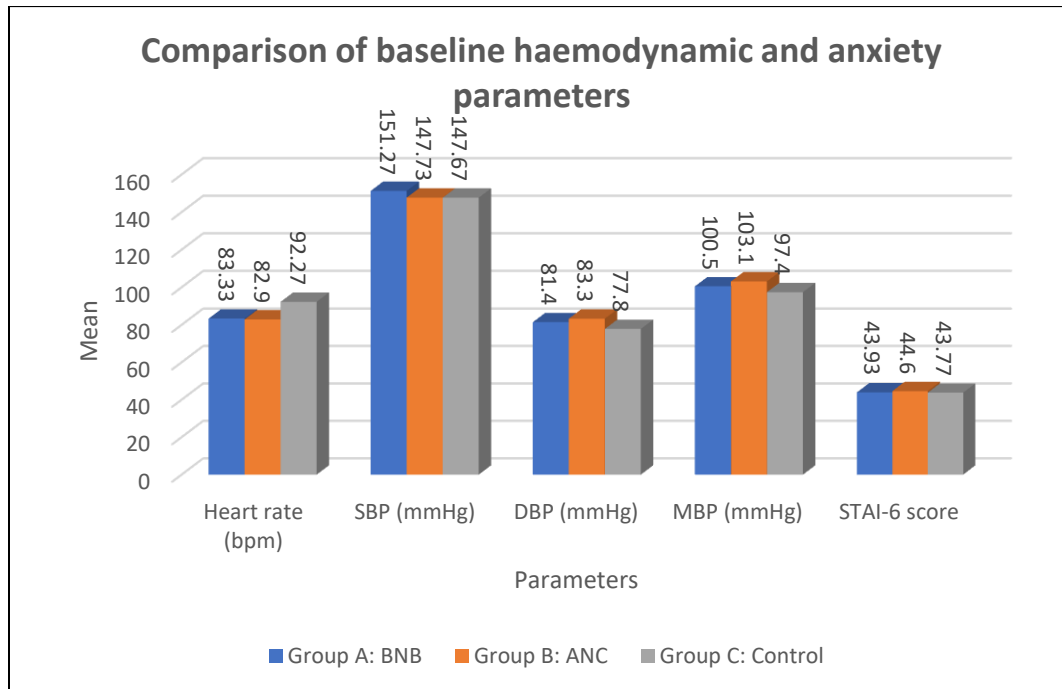


Figure 1. Comparison of baseline haemodynamic and anxiety parameters

Table 3. Comparison of anxiety scores among the study groups

Anxiety assessment	Group A: BNB	Group B: ANC	Group C: Control	p-value	Statistical test
Baseline STAI-6	43.93 ± 4.82	44.60 ± 4.00	43.77 ± 5.12	0.766	One-way ANOVA
Intraoperative STAI-6 at 30 min	32.93 ± 2.64	38.20 ± 2.52	41.50 ± 8.62	<0.001	
Reduction from baseline	11.00 ± 5.19	6.40 ± 4.21	2.27 ± 9.47	<0.001	
Postoperative STAI-6	31.10 ± 2.15	36.45 ± 2.30	43.20 ± 5.10	<0.001	

Table 4. Comparison of intraoperative heart rate among the study groups

Time	Group A: BNB	Group B: ANC	Group C: Control	p-value	Statistical test
1 min	84.13 ± 10.49	81.97 ± 13.56	92.77 ± 18.25	0.0117	One-way ANOVA
20 min	79.87 ± 9.30	81.60 ± 14.60	93.10 ± 20.18	0.0022	
40 min	78.80 ± 8.46	78.70 ± 10.94	93.63 ± 21.24	<0.001	
60 min	77.60 ± 8.20	77.90 ± 9.90	96.14 ± 19.45	<0.001	
80 min	76.97 ± 8.22	78.07 ± 11.90	97.59 ± 18.40	<0.001	
120 min	74.57 ± 7.80	76.31 ± 9.75	94.04 ± 15.11	<0.001	
160 min	73.30 ± 8.20	75.08 ± 10.14	92.50 ± 12.45	<0.001	
End of surgery	72.63 ± 7.78	73.90 ± 9.44	92.97 ± 21.20	<0.001	

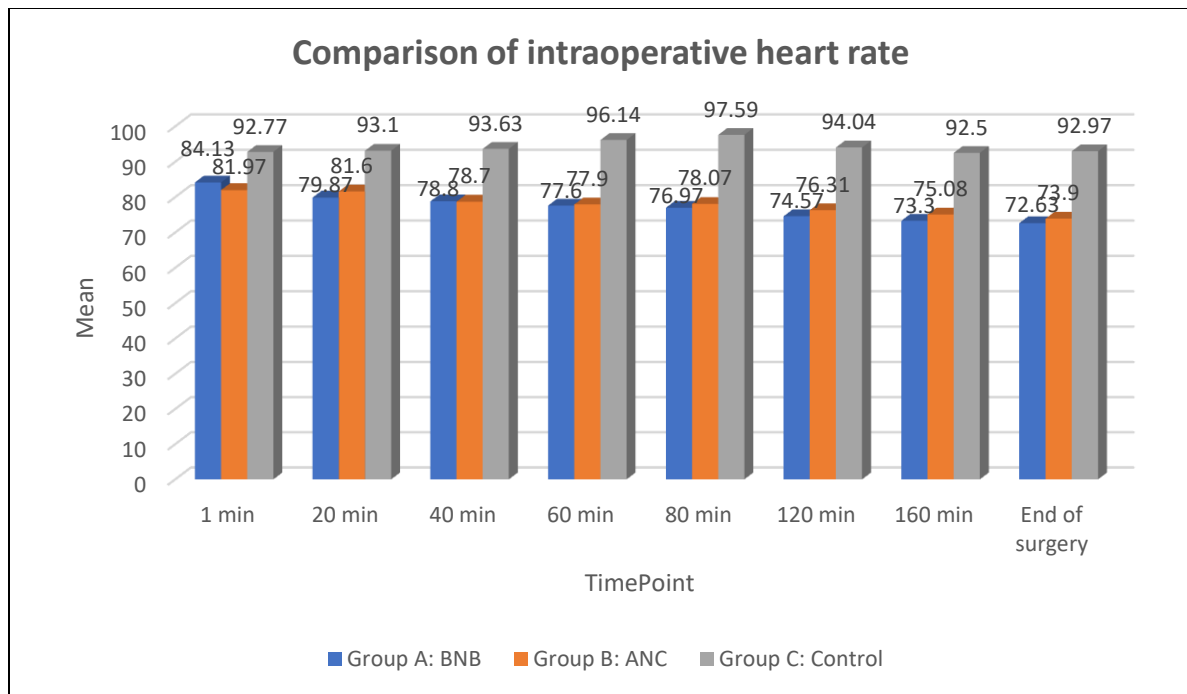


Figure 2. Comparison of intraoperative heart rate among the study groups

Table 5. Comparison of intraoperative blood pressure parameters at selected time points

Parameter/time	Group A: BNB	Group B: ANC	Group C: Control	p-value	Statistical test
SBP at 120 min	131.90 ± 12.50	133.54 ± 12.19	144.15 ± 23.14	0.016	One-way ANOVA
SBP at 160 min	128.00 ± 10.41	130.42 ± 12.38	144.12 ± 21.38	<0.001	
SBP at end of surgery	127.47 ± 10.57	129.73 ± 12.48	143.63 ± 20.33	<0.001	
DBP at end of surgery	73.13 ± 7.58	76.40 ± 8.83	77.20 ± 11.07	0.204	
MBP at 140 min	91.13 ± 8.39	92.85 ± 9.72	97.88 ± 11.72	0.039	
MBP at 160 min	91.00 ± 8.90	92.38 ± 10.48	98.96 ± 12.53	0.018	
MBP at end of surgery	90.67 ± 8.22	92.40 ± 10.01	95.73 ± 15.01	0.225	

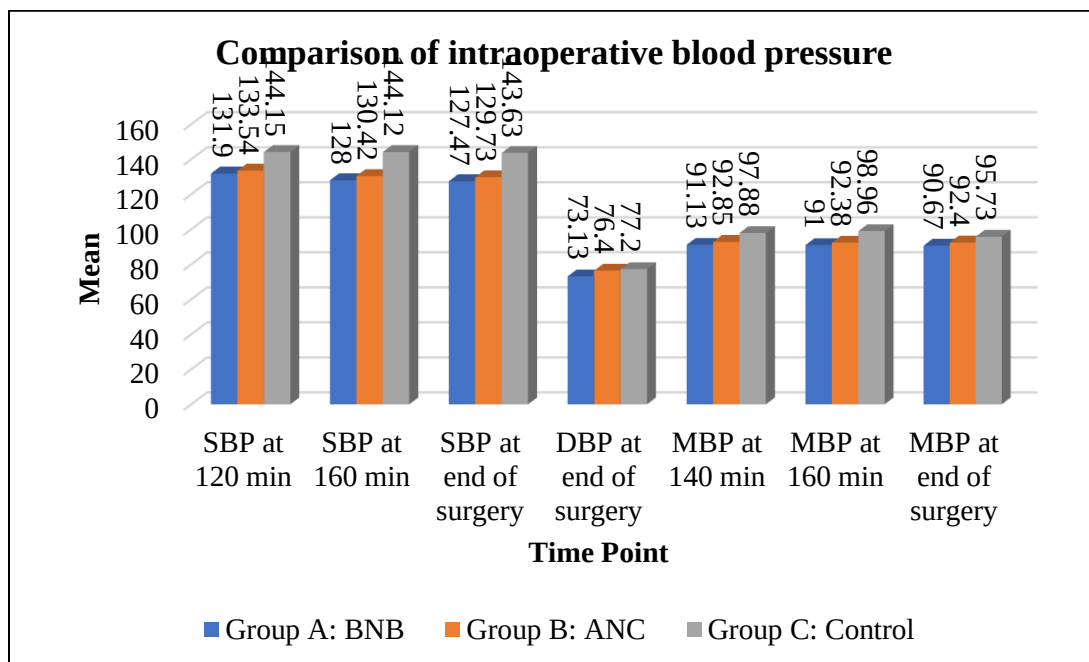


Figure 3. Comparison of intraoperative blood pressure parameters at selected time points

Table 6. Comparison of sedation, communication, and patient satisfaction

Outcome	Group A: BNB (n=30)	Group B: ANC (n=30)	Group C: Control (n=30)	p-value	Statistical test
RSS at 30 min	3.40 ± 0.62	2.73 ± 0.64	1.77 ± 0.57	<0.001	One-way ANOVA
RSS at end of surgery	5.30 ± 0.53	3.07 ± 0.58	1.77 ± 0.57	<0.001	
Communication score	4.23 ± 0.63	4.37 ± 0.49	4.90 ± 0.31	<0.001	
Patient satisfaction VAS	9.23 ± 0.77	8.33 ± 0.84	6.43 ± 1.45	<0.001	

DISCUSSION

The present study demonstrated that binaural beat auditory stimulation and active noise cancellation (ANC) reduced perioperative anxiety in patients undergoing upper-limb orthopaedic surgery under regional block, with binaural beats showing a greater effect. These findings are consistent with Ligree et al. [1] and Prasad et al. [6], who reported beneficial effects of auditory interventions on perioperative anxiety during regional/spinal anaesthesia. The three groups were comparable for age ($p=0.289$), sex ($p=0.155$), weight ($p=0.591$), and ASA physical status ($p=0.168$), minimizing the influence of baseline characteristics. Similar baseline comparability was considered in studies by Wiwatwongwana et al. [12], Bansal et al. [5], Ligree et al. [1], and Stamenkovic et al. [7]. Baseline STAI-6 scores were also comparable (43.93 ± 4.82 , 44.60 ± 4.00 , and 43.77 ± 5.12 ; $p=0.766$), supporting comparable pre-intervention anxiety. The STAI-6 is a validated measure of state anxiety as described by Marteau and Bekker [16]. At 30 minutes, STAI-6 scores were significantly lower in the binaural beat group (32.93 ± 2.64) than in the ANC (38.20 ± 2.52) and control groups (41.50 ± 8.62 ; $p<0.001$). The overall reduction was greatest with binaural beats (11.00 points), followed by ANC (6.40) and control (2.27; $p<0.001$). These findings agree with Ligree et al. [1], Wiwatwongwana et al. [12], and the meta-analysis by Garcia-Argibay et al. [11], which reported anxiolytic effects of binaural auditory stimulation. Postoperatively, anxiety remained lower in Group A (31.10 ± 2.15) than in the other groups, suggesting persistence of the anxiolytic effect beyond intraoperative exposure. This observation is consistent with the overall stress- and anxiety-reducing effects of auditory interventions reported by Bradt et al. [17] and with perioperative music findings described by Sarkar et al. [18]. Both auditory interventions were associated with lower intraoperative heart rates than control, with end-of-surgery values of 72.63 ± 7.78 , 73.90 ± 9.44 , and 92.97 ± 21.20 bpm in Groups A, B, and C, respectively ($p<0.001$). SBP also became significantly lower in the intervention groups after 120 minutes, whereas DBP remained comparable throughout. MBP differed at 140 and 160 minutes but was comparable at the end of surgery. These findings are in agreement with Bansal et al. [5], Sarkar et al. [18], and Fu et al. [19], who

described favourable effects of auditory interventions on perioperative stress and haemodynamic responses.

RSS scores were significantly higher with binaural beats at 30 minutes (3.40 ± 0.62) and at the end of surgery (5.30 ± 0.53) compared with ANC and control ($p<0.001$). These findings support the potential relaxation and sedative-sparing effects of auditory interventions described by Garcia-Argibay et al. [4], Bansal et al. [5], and Iwasaki et al. [19]. Importantly, no respiratory depression, haemodynamic instability, block failure, or other major adverse events were observed, supporting the feasibility of these non-pharmacological interventions.

Communication remained satisfactory in all groups, with mean scores above 4.0 despite headphone use. This supports the feasibility of auditory interventions without clinically important interference with intraoperative communication, consistent with Wiwatwongwana et al. [12] and Sarkar et al. [18].

Patient satisfaction was significantly highest with binaural beats (9.23 ± 0.77), followed by ANC (8.33 ± 0.84) and control (6.43 ± 1.45 ; $p<0.001$). Similar improvements in patient comfort with auditory interventions have been reported by Prasad et al. [6] and Wiwatwongwana et al. [12]. Overall, the findings suggest that binaural beat auditory stimulation may provide a useful non-pharmacological adjunct for reducing anxiety and improving the perioperative experience during upper-limb surgery under regional block.

STRENGTHS OF THE STUDY

The major strengths of this study include its prospective randomized controlled design and comparison of three groups, allowing assessment of binaural beat auditory stimulation, active noise cancellation, and standard care. The study used the STAI-6 scale to assess anxiety and evaluated additional outcomes, including haemodynamic parameters, sedation levels, communication difficulty, and patient satisfaction. The findings provide comparative evidence regarding non-pharmacological auditory interventions during upper-limb orthopaedic surgery under regional anaesthesia.

FUTURE DIRECTIONS

Future multicentre randomized controlled trials with larger sample sizes are needed to confirm these findings in diverse surgical populations. Further studies should evaluate different binaural beat frequencies, the optimal duration of auditory stimulation, postoperative anxiety and recovery outcomes, and the potential for reducing sedative medication requirements. The feasibility and safety of these interventions should also be assessed in different regional anaesthesia settings.

LIMITATIONS

The study was conducted at a single centre with a relatively small sample size of 90 patients, limiting generalizability. Blinding was not feasible, and longer-term postoperative anxiety and recovery outcomes were not evaluated.

CONCLUSION

Binaural beat auditory stimulation significantly reduced intraoperative anxiety and improved sedation and patient satisfaction compared with active noise cancellation and standard care. Both auditory interventions provided favourable haemodynamic responses without major adverse events. Binaural beats may therefore serve as a simple, safe, non-pharmacological adjunct during upper-limb orthopaedic surgery under regional block.

DECLARATIONS

Ethical Approval: The study was conducted in accordance with the Declaration of Helsinki after approval from the Institutional Ethics Committee of Rajendra Institute of Medical Sciences (RIMS), Ranchi, Jharkhand, India (IEC Registration No. ECR/769/INST/JH/2015/RR-21).

Informed Consent: Written informed consent was obtained from all participants before enrolment in the study.

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Conflict of Interest: The authors declare no conflict of interest.

Data Availability: The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable institutional and ethical requirements.

Author Contributions: Adnan Naim contributed to study conception, data collection, analysis, and manuscript preparation. Wasimul Hoda, Ladhu Lakra, and Shio Priye contributed to study supervision, clinical guidance, and critical revision of the manuscript. All authors reviewed and approved the final manuscript.

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Trial Registration: The clinical trial registration number was not provided in the manuscript. The authors should add the registration details, if applicable.

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